

disintegrating or exciting the carboniferous liquid state material to produce the single-walled carbon nanotubes.--

#### REMARKS

Claims 1-14 are pending. By this Amendment, the specification is amended, claims 1-7 are amended, and new claims 8-14 are added. No new matter is added. In view of the foregoing amendments and the following remarks, reconsideration and allowance are respectfully requested.

The attached Appendix includes marked-up copies of each rewritten paragraph (37 C.F.R. §1.121(b)(1)(iii)) and claim (37 C.F.R. §1.121(c)(1)(ii)). Support for the amendments is contained in the specification and the original claims as filed.

Applicants appreciate the courtesies shown to Applicants' representative by Examiners Lish and Hendrickson in the January 27, 2003 personal interview. Applicants' separate record of the substance of the interview is incorporated into the following remarks.

#### **I. Amendment of Specification and Claims**

Applicants amend the specification to correct misspellings and for clarity. At page 5, lines 13-23, Applicants amend the formatting of the Journet et al., *Nature* article citation. No new matter is added. At page 14, line 2 to page 15, line 4, Applicants correct the pressure units inside the vacuum chamber in Example 2. Support for this amendment is found at least at page 6, line 11, page 10, lines 8 and 26, and in Claim 1.

Applicants amend claim 1 for clarity. Specifically, amended claim 1 distinguishes the "generating arc discharges" step. Support for this amendment is found at least at page 6, line 11 and page 10, line 8.

**II. Rejection under §112**

The Office Action rejects claim 1 under 35 U.S.C. §112, second paragraph, stating that the term "at least" followed by a specific range is indefinite and unclear. Applicants respectfully traverse this rejection.

Applicants amend claim 1 to clarify that the pressure inside the system is raised to at least 1.3 kPa. Thus, claim 1 satisfies the requirement of §112. Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejection.

**III. Rejection under §102**

The Office Action rejects claims 1-4 and 7 under 35 U.S.C. §102(b), over U.S. Patent No. 5,879,684 to Withers et al. ("Withers"). Applicants respectfully traverse this rejection.

Claim 1 is drawn to a method of manufacturing single-walled carbon nanotubes using an arc discharge, under specified pressure, from a "carboniferous liquid state material comprising a metallic catalyst." Claim 4 is drawn to an apparatus that manufactures single-walled carbon nanotubes that includes "at least a pair of electrodes that generate arc discharges into a vacuum chamber to create discharge plasma, wherein at least one electrode of the pair of electrodes comprises carbon and catalytic particles." Withers does not teach or suggest a method or apparatus including each of the claimed elements.

The Office Action asserts that Withers discloses a method for producing fullerenes and nanotubes in an arc created between two electrodes, from continuously fed liquid hydrocarbon, within the range of  $10^{-6}$  to 760 torr. The Office Action states that Withers further describes the use of liquid hydrocarbons with low hydrogen/carbon ratios such as benzene and naphthalene and a process step of evacuating the system to  $10^{-3}$  torr before pressurizing the system and creating the arc. However, Withers does not teach or suggest a method of manufacturing single-walled carbon nanotubes from a carboniferous liquid state material comprising a metallic catalyst. Accordingly, Withers does not teach the method of

claim 1. For at least this reason, Withers does not anticipate claim 1. Claims 2-3 depend from claim 1, and thus, also are not anticipated by Withers. Accordingly, Applicants respectfully request reconsideration and withdrawal of this aspect of the rejection.

New claims 8-11 depend from claim 1, and thus, are not anticipated by Withers. At the January 27 interview, the Examiners indicated that the production of nanotubes utilizing carboniferous liquids that include metals may have been described in the art, although no specific art was cited. Applicants gratefully acknowledge, however, that the Examiners also indicated that specifically yttrium catalyst may not be taught or suggested in the art. New claim 9 is drawn toward a method of manufacturing single-walled carbon nanotubes that utilizes a carboniferous liquid state material comprising yttrium catalyst. For at least this additional reason, Withers does not anticipate, nor would it have rendered obvious, claim 9.

Regarding the apparatus of claim 4, the Office Action asserts that Withers discloses an apparatus for producing fullerenes and nanotubes including electrodes for arc discharge, a carbon liquid supply unit, a carrier gas supply unit, and a carbon supply feed tube. The Office Action states that Withers also describes cooling the region surrounding the reaction zone in order to enhance the collection of fullerenes. However, Withers does not teach or suggest an apparatus that produces single-walled carbon nanotubes utilizing at least a pair of electrodes that generate arc discharges into a vacuum chamber to create discharge plasma, "wherein at least one electrode of the pair of electrodes comprises carbon and catalytic particles," as claimed. Accordingly, Withers does not teach an apparatus that includes each and every element recited in claim 4.

In addition, the claimed apparatus includes "a heater that heats the carboniferous liquid state material." Withers also fails to teach or suggest this heater feature.

For at least these reasons, Withers does not anticipate claim 4. Claim 7 depends from claim 4, and thus, also is not anticipated by Withers. Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejection of claims 1-4 and 7.

New claims 12-13, depend from claim 4, and are also not anticipated by Withers.

IV. Rejection under §103

A. Withers

The Office Action rejects claim 5 under 35 U.S.C. §103(a), over Withers. Applicants respectfully traverse this rejection.

Claim 5 is drawn to an apparatus that manufactures single-walled carbon nanotubes according to Claim 4, wherein the raw material supply unit is capable of supplying a mist of the carboniferous liquid state material. Withers does not teach or suggest, and would not have rendered obvious, such an apparatus.

The Office Action states that Withers does not specifically teach an apparatus capable of spraying a mist of carbon liquid into the reaction zone, but that Withers does teach the use of very small sized solid carbon particulates in order to achieve quick and complete vaporization. The Office Action concludes that it would have been obvious to one of ordinary skill in the art to use a fine mist of liquid carbon to achieve quick and complete vaporization.

As detailed above, Withers does not teach or suggest an apparatus that produces single-walled carbon nanotubes, that includes at least a pair of electrodes that generate arc discharges into a vacuum chamber to create discharge plasma, wherein at least one electrode of the pair of electrodes comprises carbon and catalytic particles, and that includes a heater that heats the carboniferous liquid state material. While Withers arguably describes a method and apparatus for producing fullerenes, that includes the vaporization of carbon particulates, Withers does not teach or suggest that such an apparatus, including at least one electrode

comprising carbon and catalytic particles as claimed, would produce the unexpected and superior results of obtaining a high yield of single-walled carbon nanotubes. Furthermore, Withers does not teach or suggest an apparatus utilizing a heater to heat the carboniferous liquid.

For at least these reasons, Withers does not teach or suggest, and would not have rendered obvious, the apparatus of claim 5. Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejection.

**B. Withers in view of Smalley**

The Office Action rejects claim 6 under 35 U.S.C. §103(a), over Withers in view of U.S. Patent No. 5,227,038 to Smalley et al. ("Smalley"). Applicants respectfully traverse this rejection.

Claim 6 is drawn to an apparatus that manufactures single-walled carbon nanotubes according to Claim 4, further comprising a gap adjustment unit capable of adjusting a distance between the pair of the electrodes. Withers and Smalley, alone or in combination, do not teach or suggest such an apparatus.

The Office Action admits that Withers does not teach an apparatus including a gap adjustment mechanism. The Office Action attempts to overcome the deficiencies of Withers by citing Smalley. However, Smalley fails to remedy the deficiencies of Withers, and would not have rendered obvious the apparatus of claim 6.

Smalley describes an electric arc process for making fullerenes and a spring mechanism to adjust the gap between the electrodes. However, Smalley nowhere teaches or suggests the claimed apparatus for making single-walled carbon nanotubes. For instance, Smalley does not teach or suggest an apparatus including an electrode comprising carbon and catalytic particles, nor does it teach or suggest a heater that heats the carboniferous liquid state material, as claimed.

Thus, neither Withers nor Smalley teach or suggest the claimed apparatus. Moreover, the combination of Withers and Smalley would not have taught or suggested to one of ordinary skill in the art the claimed apparatus for making single-walled carbon nanotubes.

Thus, claim 6 would not have been obvious over Withers and Smalley. Applicants respectfully request reconsideration and withdrawal of this rejection.

**V. New Claim 14**

The amendment submits new claim 14 drawn to a method of producing single-walled carbon nanotubes that includes "supplying a carboniferous liquid state material to raise the pressure inside the system to a range of 39.9 kPa to 79.8 kPa." Such a method is not taught or suggested by the cited references.

Withers discloses a method for producing fullerenes. For instance, Withers states "[t]he embodiments of the instant invention for converting hydrocarbons to fullerenes utilizes techniques of intensely heating the hydrocarbons under conditions which favors the formation of fullerenes." (Col. 9, lines 38-41). Withers further expresses that the conditions "known to favor fullerene formation ... is preferably 100-200 torr." (Col. 9, lines 53-55). Although Withers generically describes possible fullerene production under a broad pressure range ( $10^{-6}$  to 760 torr), and suggests that "operating conditions ... to produce fullerene soot can be varied to produce only select fullerene molecular strengths and structures, such as only  $C_{60}$ , or other large molecular weight fullerenes, or tubular shapes," (col. 9, lines 32-37), Withers fails to provide any teaching or guidance that would have pointed one of ordinary skill in the art specifically toward the production of single-walled carbon nanotubes at a pressure of 39.9 kPa to 79.8 kPa.

For instance, Withers shows, in Figures 17a and b, the visible-ultraviolet absorption spectrum of soot collected from the examples. The results indicate the presence of fullerenes. The figures illustrate that the Withers method synthesizes almost exclusively  $C_{60}$  and  $C_{70}$

fullerenes, and primarily C<sub>60</sub> fullerenes. Withers fails to provide any examples that teach, or that would have suggested to one of ordinary skill in the art, how to produce single-walled carbon nanotubes.

In contrast, Applicants focus on the improved productivity of nanotubes over fullerenes. For example, the instant specification states, at page 13, lines 3-5, "raising the pressure inside the system enables relatively increased production of the nanotubes and lowering the pressure enables increased production of the fullerenes in reverse." The specification further states, at page 10, line 27, that the preferable pressure inside the system for producing single walled carbon nanotubes is "between 39.9 kPa (300 Torr) to 79.8 kPa (600 Torr)." As such, Applicant's method in claim 14, for producing single-walled carbon nanotubes, includes a step of supplying a carboniferous liquid state material to raise the pressure inside the system to a range of 39.9 kPa to 79.8 kPa. The production of single-walled carbon nanotubes at this pressure range is not taught or suggested by Withers, or by any of the other cited references.

Applicants disclose that the claimed method, particularly wherein the pressure inside the system is between 39.9 to 79.8 kPa (300-600 Torr), produces a superior yield of nanotubes. The yield, quality and purity of nanotubes are unexpectedly superior over anything taught or suggested in Withers. Specifically, Withers focuses its method on the production of fullerenes, disclosing an enormous pressure range ( $10^{-6}$  to 760 Torr), but expressly preferring a range of 100-200 Torr for producing fullerenes that falls outside the range of claim 14. The improved production of nanotubes, by providing the pressure inside the system between 39.9 kPa to 79.8kPa, is not taught or suggested by Withers.

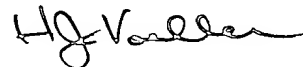
In conclusion, Applicants respectfully submit that new claim 14 is not taught or suggested by Withers, either alone or in any combination with the cited references.

VI. Conclusion

In view of the foregoing amendments and remarks, Applicants respectfully submit that this application is in condition for allowance. Favorable consideration and prompt allowance are earnestly solicited.

Should the Examiner believe that anything further is desirable in order to place this application in better condition for allowance, the Examiner is requested to contact Applicants' representative at the telephone number listed below.

Respectfully submitted,



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Attachment:  
Appendix

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